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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

SOME MICROSCOPIC CHARACTERISTICS OF THE BEND AND THE ELLENBURGER LIMESTONES[1]

by

J. A. UDDEN AND V. V. WAITE

During the development of the oil fields in Central and North-Central Texas the need of making careful observations on the lower formation explored, was recognized by many oil men. It was desirable to identify the productive horizons and to distinguish them from the underlying non-productive formation usually known as the Ellenburger Limestone. Many operators submitted samples to the Bureau of Economic Geology to be examined for this purpose. It was found that identification of most samples could be made from thin sections of fragments included in the material submitted. At the request of a number of oil geologists a set of thin sections, showing the most important characteristics of the formations mentioned, were selected for photographing, which photographs, with some brief typewritten notes, were prepared and sold. Several small editions were thus distributed. The demand for copies still exists, and is sufficiently insistent, as it seems, to justify the publication of a printed edition. No pretense is made to a scientific treatment of the lithology of the formations mentioned. The photographs were made under the direction of Mr. V. V. Waite, who was assisant geologist in the Bureau of Economic Geology at the time. The senior author is responsible for the notes. He also helped in the selection of the material photographed. Publication is now made in the hope that the bulletin may be found useful to "subsurface" geologists, when called upon to make prompt, "offhand," determinations for operators exploring the lowest oil horizon in Texas. It will be noted that two series of photographs are presented.

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[1]Revised manuscript submitted, Dec., 1926. Published, Feb., 1927.

Eight of these photographs illustrate sections from the Ellenburger Limestone, and nine sections are from the Bend formation.

Lately Mr. M. I. Goldman has described a limestone, identified as Boone in age, resting on the Ellenburger in San Saba County.[2] It is quite likely that other, and possibly larger remnants of Boone material occur farther north and may have been penetrated in some borings. They are to be looked for between the Ellenburger and the Bend. Fortunate taking of samples may reveal such remnants of the Boone age.

But the purpose of this paper is to aid in locating the top of the Ellenburger Limestone, which is an extensive feature in North-Central Texas. Meanwhile the reader is referred to Goldman's description of the Boone Age Limestone when opportunity offers to make critical observations.

THE ELLENBURGER LIMESTONE

The Ellenburger Limestone is a formation a thousand, or more, feet thick, underlying the Bend formation in the north-central part of Texas. It comes to the surface in parts of McCulloch, San Saba, Lampasas, Burnet, Gillespie, and other counties. It is a formation poor in fossils and for that reason its age is not accurately known.

The upper hundred feet, more or less, of the Ellenburger Limestone is a fine-grained calcareous limestone. The lower 900 feet, more or less, is essentially a dolomitic marble varying in texture from fine crystalline above, to coarser crystalline below. This lower part of the limestone can easily be recognized by its wholly crystalline texture which for any individual sample is apt to be uniform. The Ellenburger contains some layers that are oolitic, and it also contains some flint or chert, mostly white.

In practice, the item of principal importance is to know the characteristic features of the textures of the upper fifty

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[2]Roundy, V. P., Girty, G. H., and Goldman, M. I., Mississippian Formation of San Saba County, Texas, U. S. Geol. Surv. Prof. Paper 146, 1926.

feet of this formation. Since there is an unconformity between the Bend and the Ellenburger, since a thin limestone of Boone age has been found to immediately overlie the Ellenburger at one place in San Saba County, and as the texture of the upper part of the Ellenburger varies for different layers, the limestone layers encountered immediately under the lower Bend shale will not always be alike.

The characteristic textures of the upper fifty or hundred feet of the Ellenburger limestone may be briefly summarized as follows:

1. As a general rule the texture of this limestone is quite uniform in any particular sample. Such is not usually the case in the Bend.

2. In the upper fifty feet of the Ellenburger, some layers of the rock have a texture of the finest of lithographic limestone and the crystals are too small to be clearly made out under a one-fourth-inch objective. With a magnification of thirty or forty diameters, the crystals in this exceedingly fine-textured rock can hardly be seen. Under a one-sixth-inch objective and in very thin slides, it appears quite clear.

3. Some of the layers encountered in the upper 200 feet of the Ellenburger Limestone contain scattered, very large rhombohedral crystals, presumably of dolomite. In some specimens these crystals appear in skeletal outlines, their interiors showing the fine texture of the matrix in which they lie imbedded.

4. Thin sections from some layers in the upper fifty feet of the Ellenburger Limestone are characterized by a dappled appearance. Rounded spots of subequal size consist of finely crystalline material and are separated from each other by a matrix consisting of coarser and clearer crystals. In most samples the fine-textured areas are of uniform size in any one sample. In different samples they may have different sizes. It is believed that these different textures are caused by some progressive concretionary rearrangement in the crystallization of the rock. This seems to be developed in different stages in different layers. In some specimens this dappled texture can barely be made out, in others it is pronounced and clear. One characteristic of

this rock is that the two textures represented in the dapples and in the matrix often merge into each other without any clearly defined line of separation. To this last statement one or two exceptions have been noted, where oval or circular rings appear; but these have the appearance of being the result of concretionary changes rather than traces of imbedded organisms.

5. Some thin sections from the upper fifty feet of the Ellenburger show a texture which may be characterized as that of a microscopic "crushed breccia." This also shows a blotchy texture. The rock consists of rounded lumps of fine texture, separated by a matrix of more coarsely crystalline and clearer material. The blotched areas of finer material in this rock are of variable size and some of them occasionally show fissures or other small areas filled with calcite.

THE BEND FORMATION

The Bend is a formation of limestones and shales overlying the Ellenburger Limestone. The limestones of this formation are quite unlike those found higher in the Anthracolitic section. Their most marked difference from the Ellenburger Limestone is that the Bend limestone, even in small fragments, usually show some traces of organic structures. The following can be regarded as characteristic features of the Bend sediments:

1. Spicules of sponges are more or less frequent throughout the entire section, in the shales as well as in the limestone, and are particularly common in the uppermost part of the formation.

2. Most Bend limestones have a darker color than most of the later Pennsylvania limestones.

3. The limestones, as well as the shales, are slightly more indurated than later Pennsylvanian deposits of similar kinds. Most of the shales do not readily distintegrate in water so as to form mud in drilling, or when washed.

4. In its texture, the Bend Limestone may be characterized as quite fine-grained. It has evidently been subjected to an incipient hydrous metamorphism. This metaphorphism

has resulted in secondary crystallization of part of the calcareous material, and almost throughout the whole section the limestone in the formation is affected by this change, so as to contain irregular tracts of crystalline material. These areas are not sharply defined from the rest of the rock, which consists of unaltered granular material with imbedded organic fragments. In the thin sections from the Bartles and Dumesnil well, Bough No. 1, in Brown County, the crystallized material constitutes about 30 per cent of the rock. The ratio is quite constant throughout the formation. It has also been found that the quantity of organic fragments is greater in the lower part of the formation and is smaller in the limestones which are least affected by secondary change.

5. A recurrent crystalline peculiarity is the occurrence throughout the entire section of microscopic rhombohedral crystals of calcite that lie scattered in the rock. These crystals occur in the shales as well as in the limestones.

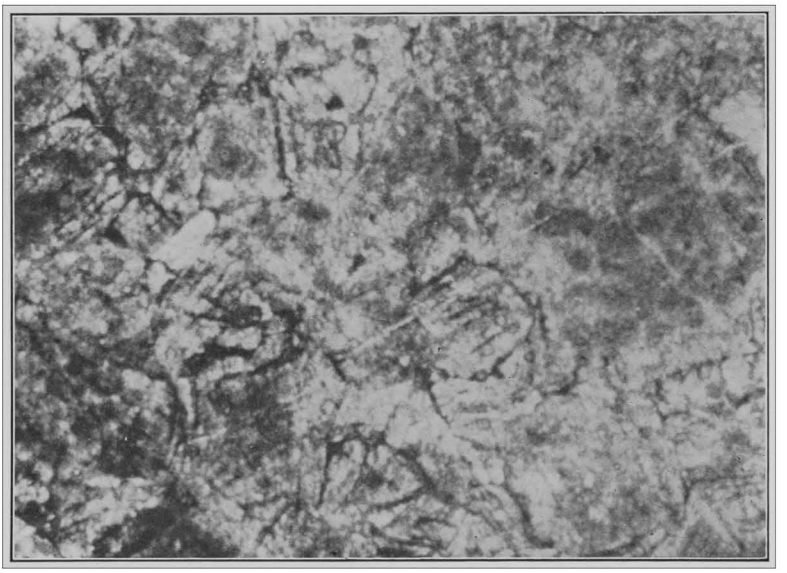
6. Imbedded round grains of glauconite of a pale bluish-green color are present in the lower third of the section examined. In some samples the iron in these glauconite grains is partly oxidized, giving the grains a dull yellowish or brownish color. This glauconite is readily distinguished from the glauconite occurring in the Cambrian. The latter is always of a bright green color, and it is more translucent than that in the Bend. It is also to be noted that the Bend glauconite grains are slightly larger in size and more nearly spherical in shape than the glauconite of other formations. These characteristics are likewise common to the glauconite in the Dimple formation in the Marathon country. It is believed that the Bend and the Dimple are of the same age, at least in part.

7. Organic fragments are present in all of the limestones but are most abundant in the limestones in the lower half of the Bend. The fauna is characterized by the occurrence of small spines of palechinids, spicules of sponges, often in great profusion, valves of ostracods, and by a relative scarcity of remains of brachiopods, molluscs, and bryozoa. Fusu-

lina occurs in the upper half of the section. Endothyra and other small foraminifera are not particularly abundant. One of these is believed to be a Climacammina or a Bigenerina of somewhat large size. Though observations are naturally limited to small fragments, they leave a decided impression that the Bend fauna is characterized by diminutive forms. A very small flat Ammodiscus has been noted, smaller than such as occur in later beds, in the Pennsylvanian.

DESCRIPTIONS OF SOME THIN SECTIONS FROM THE ELLENBURGER AND BEND FORMATIONS

Detailed descriptions of thin sections of the Ellenburger and Bend formations giving the microscopic characteristics of the rocks are given in the explanations of the plates illustrating these sections. Plates 1 to 4 and Figure 1, Plate 5, illustrate sections of the Ellenburger; while Figure 2 of Plate 5 and Plates 6 to 9 inclusive are of the Bend.



Section of Ellenburger Limestone

A coarsely crystalline dolomite. The crystals are affected by fractures which follow the cleavage planes and which appear to have been filled with darker material. The section represents rock 350 feet below the top of the Ellenburger in the Bartles and Dumesnil Bough well No. 1, in the northern part of Brown County. Magnified about 45 diameters.

PLATE 2

Sections of Ellenburger Limestone

Figure 1. A very fine-grained limestone. Under higher magnification this is seen to be wholly crystalline. In the finely crystalline mass there have developed large crystals, apparently of dolomite, some of which measure several millimeters in diameter. These crystals are dark in the interior, but have an external layer of clear material. At Ranger this rock was noted about 375 feet below the Bend in the Farabee, Woods and Norton, *et al.* Brashear well No. 1, Eastland County. Magnified about 25 diameters.

Figure 2. A limestone consisting of a fine-grained matrix in which are imbedded crystals of dolomite of relatively large size. In places the matrix has dark blotches possibly caused by the presence of bituminous material. The section is seen to be traversed by irregular small calcite veins. This section is from about 375 feet below the Bend, in the Farabee, Woods and Norton, *et al.* Brashear well No. 1, Eastland County. Magnified about 25 diameters.

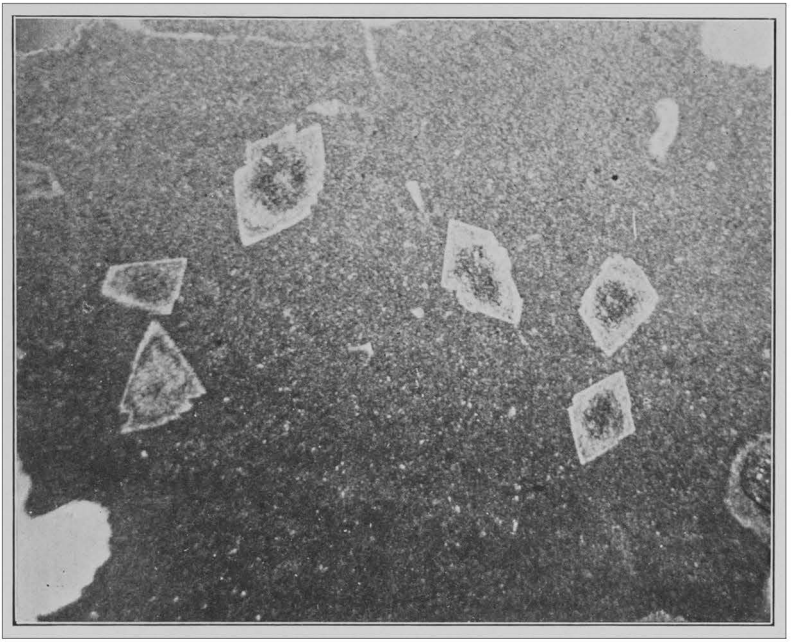


Figure 1

Figure 2

PLATE 3

Sections of Ellenburger Limestone

Figure 1. A limestone consisting of a matrix of clear crystalline material in which are partly rounded and partly angular bodies of finely granular material, appearing darker than the matrix. The blotches of finer material vary in size, the largest being several times the size of the smaller. A few of the granular blotches show concavities on their exterior outlines. Though the rock somewhat resembles an oolitic limestone, the general aspect of the texture suggests that some kind of healed fracturing is responsible for the coarse crystallization of the matrix. This section represents layers about 115 feet below the Bend, north of Brownwood, in the Bartles and Dumesnil Bough well No. 1. Magnified about 50 diameters. In certain cases it has been noted that this texture occurred in close association with cavernous openings in limestones.

Figure 2. Oolitic limestone, in which the oolitic spherules are seen to be of quite uniform size. It will be noted that some of the spherules show an outer crust with a radiate structure. This limestone occurs about 130 feet below the top of the Ellenburger in the Sterling Oil Company's W. A. Whittenburg well No. 1, in Mills County. It is associated with oolitic flint. Magnified about 25 diameters.

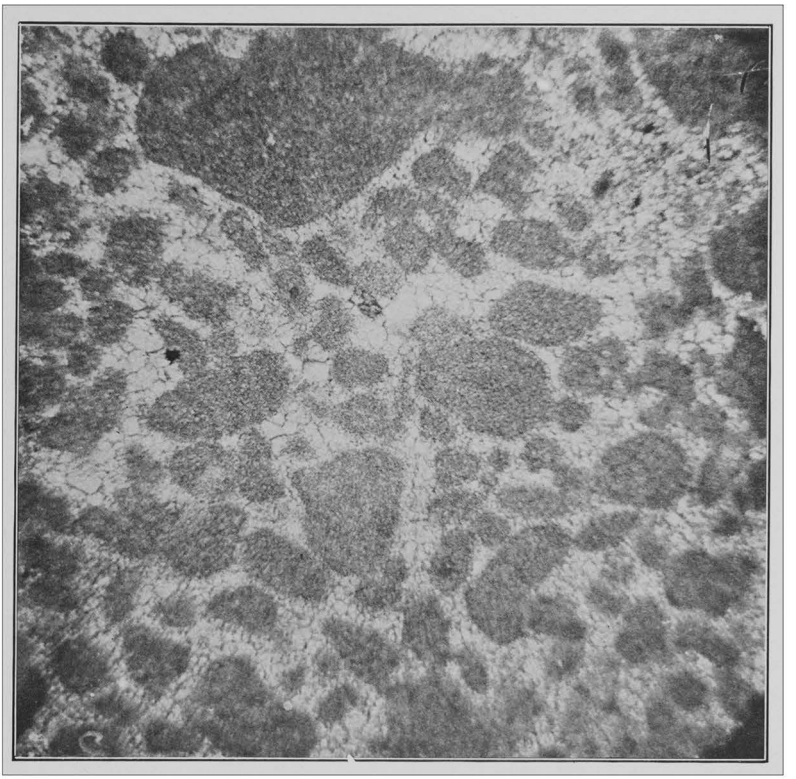


Figure 1

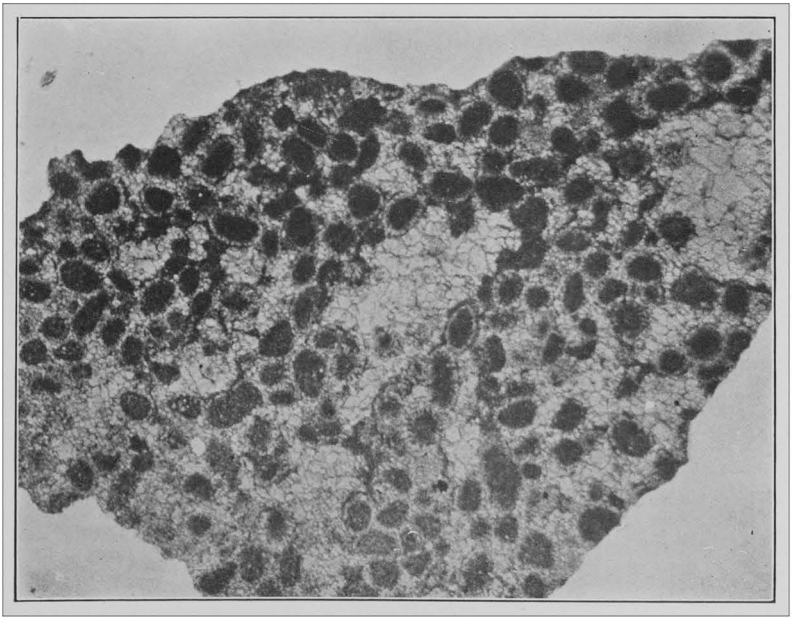


Figure 2

PLATE 4

Sections of Ellenburger Limestone

Figure 1. A part of this section shows an obscurely mottled texture. In this, as a matrix, there are seen spherical bodies of radiate crystalline structure. Where the section traverses the center of these spherical bodies it discloses a section of a sphere, the radiating crystals appear to meet in the center. This rock comes from a level about ninety feet below the top of the Ellenburger in the Sterling Oil Company's W. A. Whittenburg well No. 1, three miles north from the Colorado River, two miles east from Ebony, in Mills County. Magnified about 25 diameters.

Figure 2. A limestone consisting of a clear matrix of relatively large-sized calcite crystals in which lie imbedded large and small oval bodies of finer texture. These appear dark in the section. The larger dark bodies are in some cases themselves made up of smaller bodies suggesting a repetition of brecciation and healing. Some of the smaller rounded bodies show a development of radiating crystals externally. The section is from a layer in the upper ninety feet of the Ellenburger Limestone in the Sterling Oil Company's W. A. Whittenburg well No. 1, in Mills County. Magnified about 25 diameters.

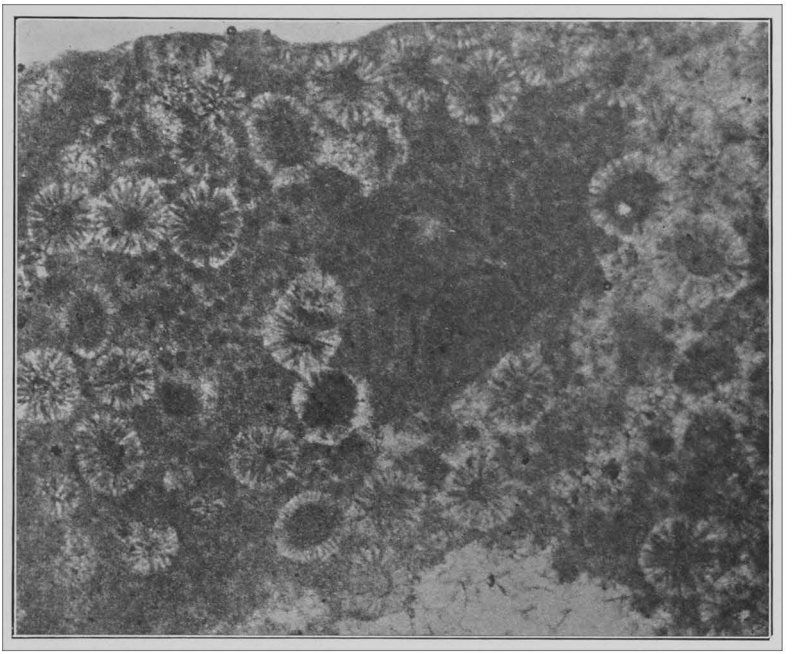


Figure 1

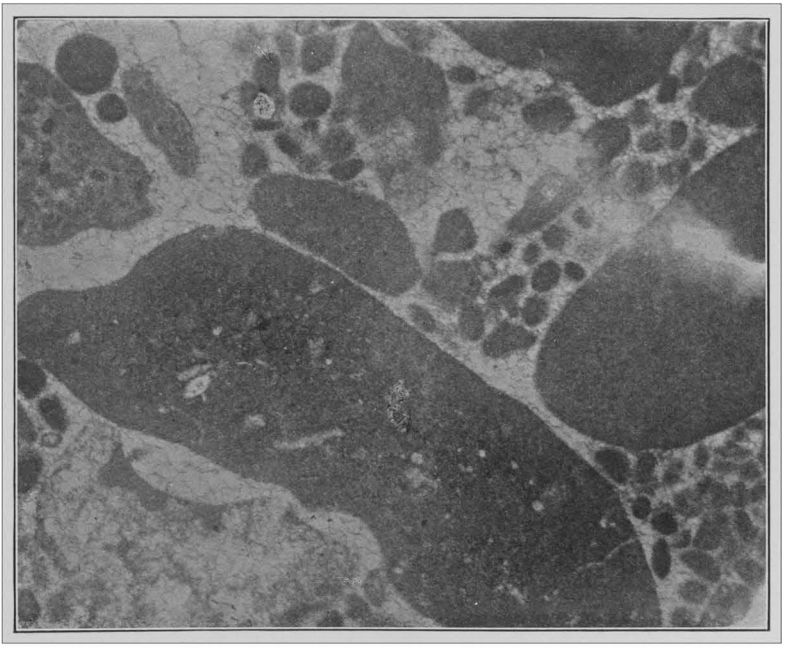


Figure 2

PLATE 5

Sections of Ellenburger Limestone (Fig. 1) and Bend Limestone (Fig. 2)

Figure 1. Oolitic limestone. The fine texture of the material in the oolitic spherules causes them to appear dark. The matrix is more coarsely crystalline and allows more light to pass through than do the spherules. This section is from the Graham, Thomas and Ludlow Agney well No. 1, in Brown County. It comes from the upper part of the Ellenburger Limestone. Magnified about 25 diameters.

Figure 2. A bituminous limestone containing spicules of sponges in great profusion. The matrix containing these spicules consists of mostly granular calcareous material. From an outcrop of the Bend Limestone in San Saba County. Magnified about 25 diameters.

Cuttings of this rock, often called "Spicule Rock," have been found in almost all wells penetrating the Bend in Central Texas. Where exposed along the San Saba River, pieces are frequently found from which all calcareous material (matrix) has been leached out. Such pieces are naturally light in weight, as they consist of a felt-work of the siliceous spicules which remain. It has been used, locally, as a scouring material. By crushing it, washing, and examining under a microscope various forms of spicules may be found, such as dimeres, trimeres, and hexameres, which are fortuitously also to be observed in cuttings from deep borings. Sponge spicules are abundant in some parts of the Dimple formation in West Texas. There they attain lengths of from one to five inches.

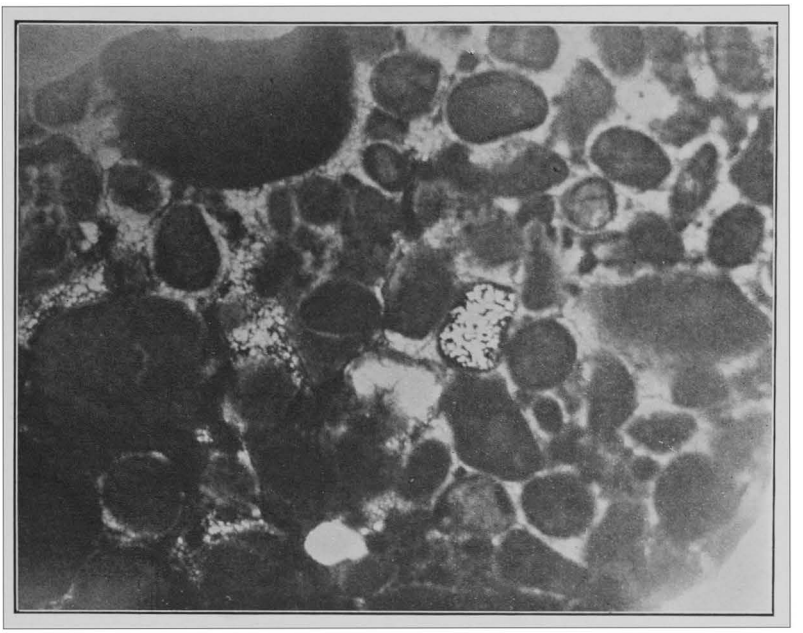


Figure 1

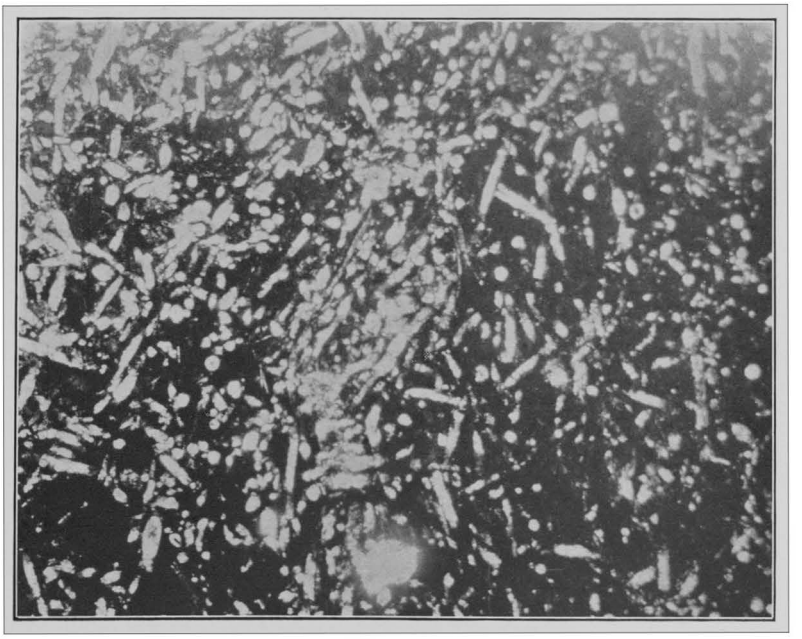


Figure 2

PLATE 6

Sections of Bend Limestone

Figure 1. Bituminous limestone consisting largely of organic fragments, among which are several large sponge spicules; some seen in longitudinal and some in transverse sections. Several of the dark grains noted in this section consist of pale, yellowish glauconite. Some organic fragments are evidently broken pieces of ostracod shells. From the Bartles and Dumenil Bough well No. 1, Brown County, from about 200 feet below the top of the Bend Limestone. Magnified about 25 diameters.

Figure 2. A bituminous organic-fragmental limestone. The organic fragments are variable in size. A Climacammina(?) in oblique section is a conspicuous object. Some of the larger fragments exhibit a cancellated texture, suggesting that they may be fragments of crinoid stems. The dark blotches in the photograph are caused by impregnating bituminous material. This sample comes from about eighty feet below the top of the Marble Falls Limestone in the Bartles and Dumesnil Bough well No. 1, Brown County. Magnified about 25 diameters.

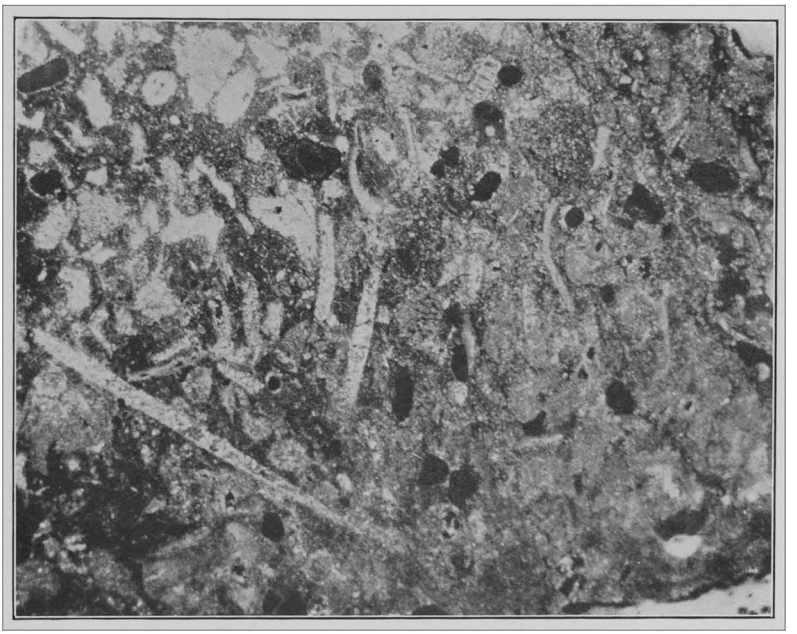


Figure 1

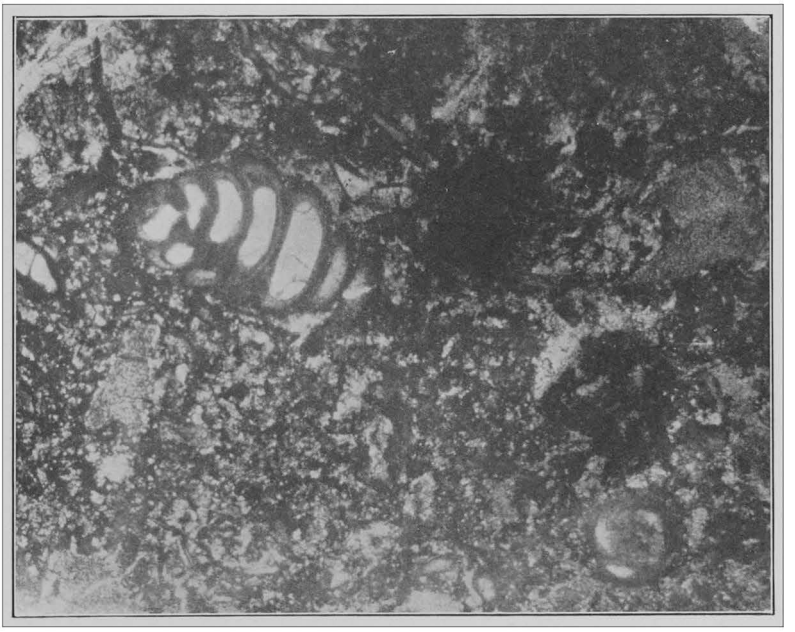


Figure 2

PLATE 7

Sections of Bend Limestone

Figure 1. An organic fragmental limestone containing some unidentified organic structures probably related to the lithisid sponges or related to stromatoporoids. The greater part of the rock appears to consist of structures of this kind. From the Key well No. 1, Lampasas County, at a depth of 210 feet. This is from the lower part of the Bend Limestone. Magnified about 25 diameters.

Figure 2. An organic limestone in which the matrix has been changed to a crystalline condition. The fossil fragments stand out in clear outline. Among these may be recognized fragments of ostracod valves, Endothyra, striated fragments of palechinid spines, and occasional fragments of bryozoa. With these are many unrecognizable organic fragments, most of which are probably from foraminifera. This section is from the Bartles and Dumesnil Bough well No. 1, about sixty-five feet below the top of the Bend Limestone. Magnified about 25 diameters.

Figure 1

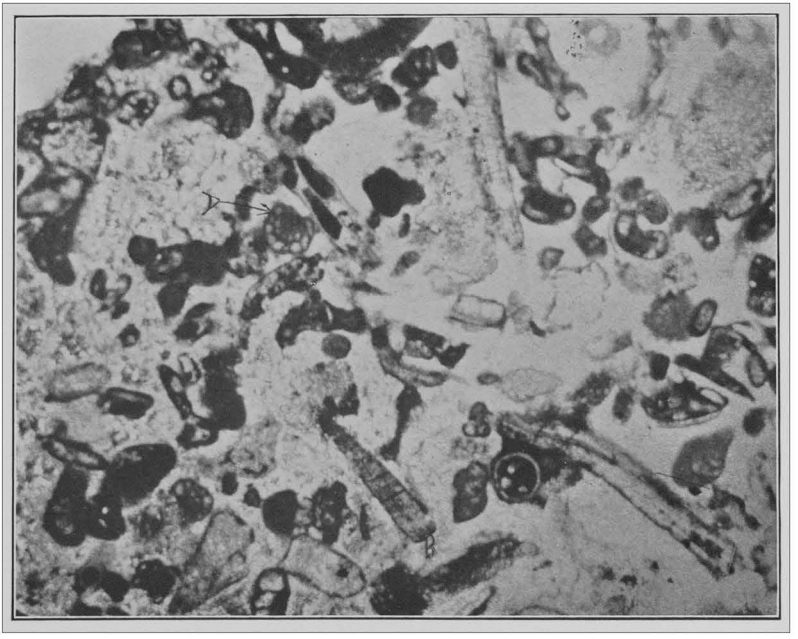


Figure 2

PLATE 8

Sections of Bend Limestone

Figure 1. An organic limestone consisting of tubular curving structures imbedded in a crystalline matrix. This section is from the Bartles and Dumesnil Bough well No. 1, Brown County, at a depth of 2,090 feet. Magnified about 50 diameters. The walls of the tubules seem to consist of granular material as in agglutinate-shelled foraminifera.

Figure 2. An organic limestone consisting of some tubular organic structures imbedded in a crystalline matrix. The tubules are curved and sometimes branched. The structures of this kind have been noted at from 115 to 190 feet below the top of the Bend Limestone in the Bartles and Dumesnil Bough No. 1 well, Brown County. Magnified about 50 diameters. Evidently this form is identical with the tubular organic structures shown in the preceding figure.

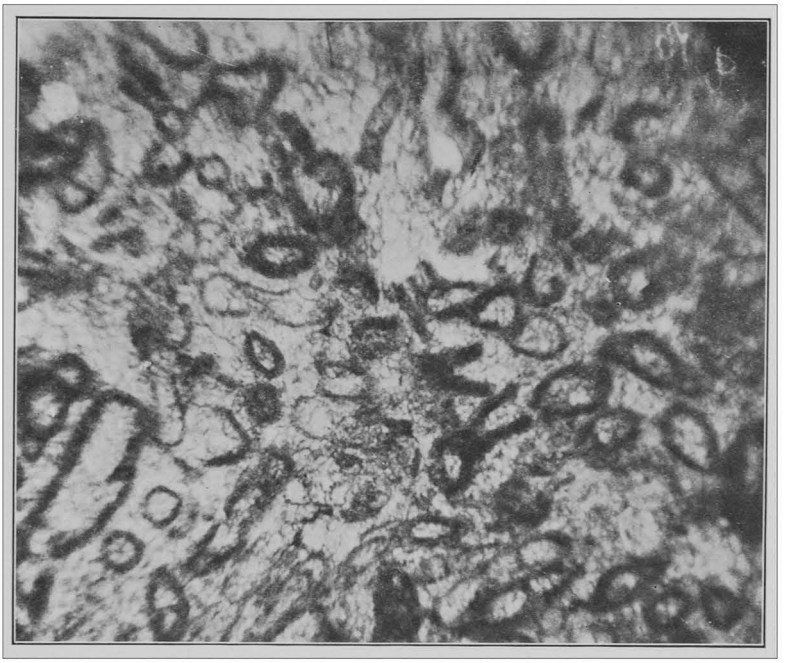


Figure 1

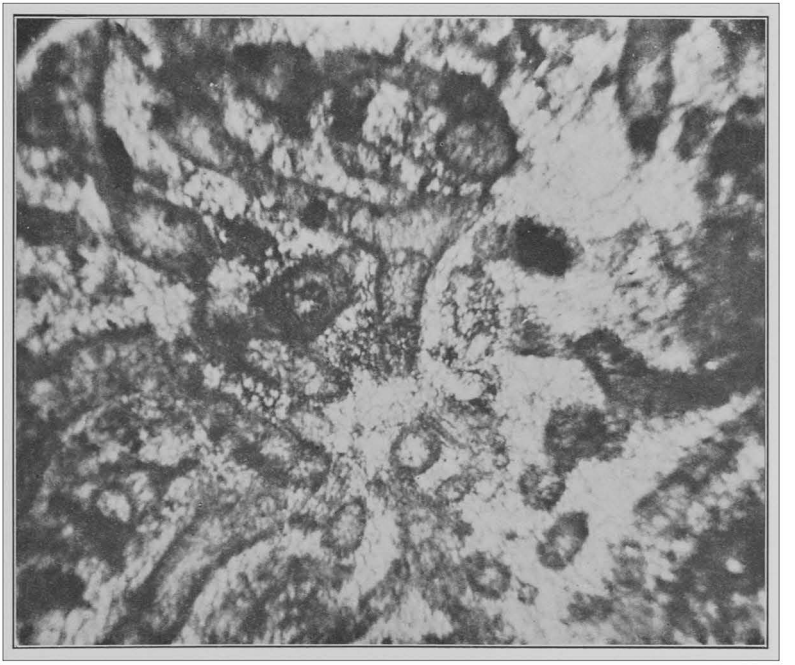


Figure 2

PLATE 9

Sections of Bend Limestone

Figure 1. Bituminous limestone showing a few sponge spicules, a Trochammina at *A*, and a crinoid stem at *B*. This latter is recognizable from its finely cancellated texture. The entire rock consists of organic fragments in a crystalline or granular matrix. This section comes from the Bartles and Dumesnil Bough well No. 1, Brown County, and is about 120 feet below the top of the Marble Falls Limestone. Magnified about 25 diamters.

Figure 2. An organic fragmental limestone containing grains of glauconite. Some of the glauconite occurs lining the interior of valves of ostracods. Other glauconite forms separate rounded grains. These grains are partly of an olive-green but mostly of a dull yellow color. In the section there appear a few transverse sections of what are probably minute spines of palechinids. A few sponge spicules are also to be seen. The palechinid spines exhibit a very finely cancellated skeletal texture. This section is from the Bartles and Dumesnil Bough well No. 1, at a depth of about 270 feet below the top of the Bend Limestone. Magnified about 25 diameters.

Figure 1

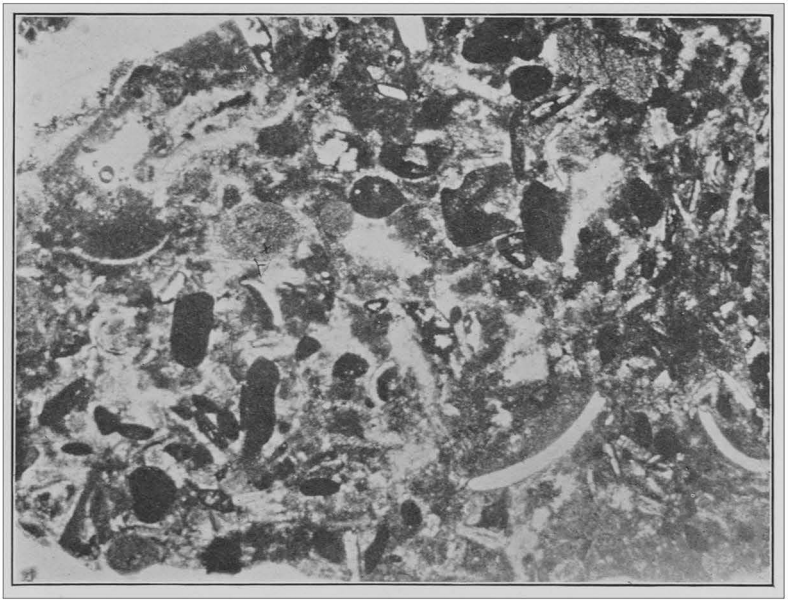


Figure 2